THE SALINITY OF INSHORE OCEANIC WATERS OF AUSTRALASIA IN RELATION TO FISHES.

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(*Communicated by Professor H. G. Chapman*).
[Read 25th November, 1925.]

Introduction.

According to the Challenger Handbook (*Science of the Sea*, 1912), seawater contains from 3.5% to 4% of salts, but if the percentage of salt falls considerably, true marine algae are scarce. Marine algae have an optimum, maximum and minimum limit with regard to salinity as well as with regard to light and temperature. The object of this paper is to introduce the study of the salinity of comparative inshore areas of Australasian waters to shed light on the distribution of plankton and on fish life. We believe that too many investigators in the past have neglected to balance the whole of the influences at work in the destruction of plankton, and too many theories with too little observation behind them have been made on the influence of minor currents and bacterial action in temperate zones of both hemispheres. The collection of a large number of samples on a given day at tide specified has enabled us to prepare a paper along different lines from other observers chiefly owing to the fact that samples have been *simultaneously* collected over so large an area of ocean.

Analyses made by Dittmar show that the relative proportions of the minor constituent salts of seawater to the major sodium chloride content are remarkably constant, and it was therefore considered that complete analysis of the minor salts would serve no useful purpose. We therefore confined our attention to accurate determinations of chlorine present in chlorides, which may be taken as a satisfactory index of total salinity. The chlorine determinations were made volumetrically by titration with silver nitrate, which had been carefully standardized against both British Drug House (Analytical Reagent) and Merck's (Guaranteed Reagent) sodium chloride. An analysis was, however, made of a typical New Zealand seawater and was found to correspond closely to the mean analysis of Dittmar (both calculated to the same chlorine content). We have preferred to express our results in terms of percentage of chlorine (as chlorides) rather than as total solids calculated from these values by an arbitrary factor after the manner of Dittmar (in Challenger Reports) and others.

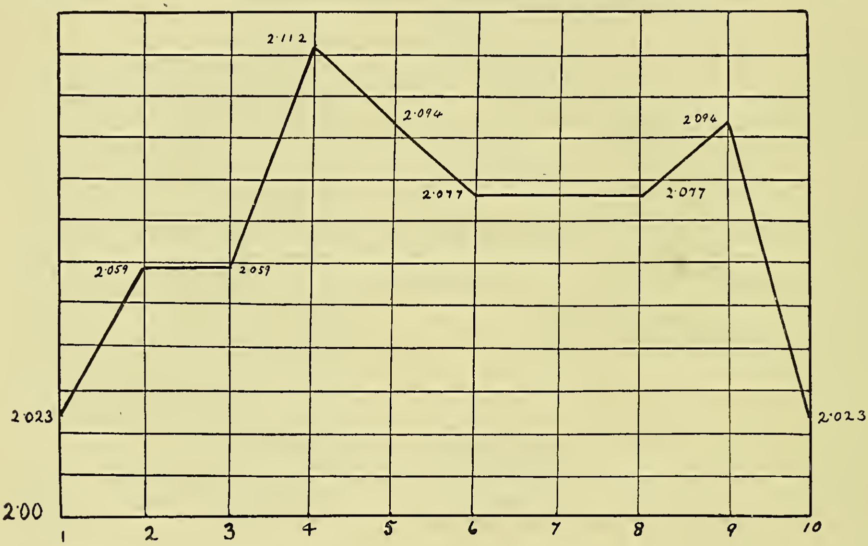
In connection with assistance rendered in the collection of samples, we desire to make special mention of the following, to each of whom we are indebted for assistance:—Mr. E. B. Harkness, State Fisheries Dept., Sydney; Mr. F. Lewis, Chief Inspector of Fisheries, Melbourne; Mr. Bruce, Chief Inspector of Fisheries, Adelaide; Mr. D. Carter, N. Z. Union S. S. Co., Auckland; Capt. Hammond, Northern S. S. Co.; Mr. S. Reid, Portland Cement Co.; Miss A. I. Mackay, Urenui School; and Mr. E. D. Crawford, Tararu.

Salinity Determinations of Australian Seawater.

No.	Date.	Locality.	Collected by.	Chlorine per cent.
1	23rd Oct., 1923	Fremantle	The Harbour Master	2.094
2	12th Dec., 1923	Fremantle	The Harbour Master	2.094
3	6th Sept., 1923	Port Adelaide ..	Mr. Bruce	2.112
4	6th Sept., 1923	Port Lincoln ...	Mr. W. D. Randall	2.112
5	6th Sept., 1923	Port Pirie	Mr. A. Frinsdorf ..	2.467
6	6th Sept., 1923	South Channel, Port Phillip ..	Mr. W. J. McCulloch	2.041
7	6th Sept., 1923	Westernport Bay	Mr. G. J. Ward ..	2.077
8	6th Sept., 1923	Bass Strait	Mr. C. J. Beck	2.077
9	6th Sept., 1923	Port Phillip Bay	Mr. Lewis	2.059
10	6th Sept., 1923	Port Fairy	Mr. J. Northey	2.077
11	5th Sept., 1923	North of Cape Hawke	S.S. Maianbar (per Mr. E. B. Harkness)	2.094
12	5th Sept., 1923	East of Cape Hawke	S.S. Maianbar (per Mr. E. B. Harkness)	2.094
13	5th Sept., 1923	South of Cape Hawke	S.S. Maianbar (per Mr. E. B. Harkness)	2.094
14	5th Sept., 1923	Off Camden Haven	S.S. Yulgilbar (per Mr. E. B. Harkness)	2.094
15	5th Sept., 1923	S. Lat. 29° 44′ .. E. Long. 153° 21½′	S.S. Pulganbar (per Mr. E. B. Harkness)	2.094
16	5th Sept., 1923	S. Lat. 29° 35′ .. E. Long. 153° 23′	S.S. Pulganbar (per Mr. E. B. Harkness)	2.094
17	5th Sept., 1923	Korogoro Point	S.S. Wollongbar (per Mr. E. B. Harkness)	2.094
18	5th Sept., 1923	Korogoro Point	S.S. Wollongbar (per Mr. E. B. Harkness)	2.094
19	5th Sept., 1923	East of Tacking Point	S.S. Wollongbar (per Mr. E. B. Harkness)	2.094
20	5th Sept., 1923	S. Lat. 32° 54′ .. E. Long 151° 55′	(per Mr. E. B. Harkness)	2.077
21	5th Sept., 1923	North of Smoky Cape	J. Anderson (per Mr. E. B. Harkness)	2.077
22	12th Dec., 1923	Rockhampton ..	Mr. N. Ladlay	2.147

Australian samples.—The average chlorine percentage in samples of water collected on the Australian coasts was 2.102. This estimate includes the abnormal sample secured at Port Pirie. Taking the Australian States separately, we find average salinities to give results very similar in most cases. Western Australia, with 2.094 on both the 23rd October and the 12th December, has apparently a fairly constant salinity at Port Fremantle during the early summer months. As might perhaps have been expected, samples from Spencer and St. Vincent Gulfs showed the highest recorded salinity. Evidently Kangaroo Island, off Point Victoria, effectually prevents the influence of the volume of water brought down by the river Murray lowering the salinity of Investigator Strait and the Great Australian Bight. The average of South Australian samples was 2.230% chlorine. It is interesting to note that Westernport Bay, Bass Strait, and Port Fairy had each 2.077% chlorine, which amount is also that of the highest recorded sample from New Zealand, taken by Captain Aspden in the Bay of Plenty.

Tasman Sea.—In order to ascertain something of the nature of the water between New Zealand and Australia, we considered it advisable to have samples collected for us at regular intervals across the Tasman Sea by the mail steamer between Wellington and Sydney. On being approached, the Chief Engineer on the S.S. Ulimaroa kindly consented to do this for us, and some ten samples were taken at regular intervals of from nine to ten hours, the first being collected nine hours after leaving Wellington Harbour and the last in Sydney Harbour. By a curious coincidence these two samples of water had the same salinity. It would appear at this season that, some three hundred miles off the New Zealand coast, the salinity rises slightly and remains higher than usual around New Zealand until just before the Australian coast when a further rise is noticeable. The total distance from Wellington to Sydney is 1,240 miles, and, from our graph below, we may determine that the influence of tropical waters in the Tasman Sea was at this season strongest on the eastern coast-line of Australia and also several hundred miles west of New Zealand. There is, of course, the possibility that the higher



Intervals of 9 hours each.

Graph to indicate changing salinity between Wellington, N.Z., and Sydney, August, 1923.

Salinity Determinations: Tasman Sea, Wellington to Sydney.

No.	Date.	Locality.	Chlorine per cent.
1	24th Aug., 1923	40° 15′ S. Lat. 172° 41′ E. Long	2.023
2	25th Aug., 1923	39° 30′ S. Lat. 170° 20′ E. Long	2.059
3	25th Aug., 1923	38° 50′ S. Lat. 167° 33′ E. Long	2.059
4	25th Aug., 1923	38° 02′ S. Lat. 164° 47′ E. Long	2.112
5	26th Aug., 1923	37° 12′ S. Lat. 162° 08′ E. Long	2.094
6	26th Aug., 1923	36° 31′ S. Lat. 159° 33′ E. Long	2.077
7	27th Aug., 1923	35° 45′ S. Lat. 156° 59′ E. Long	2.077
8	27th Aug., 1923	35° 02′ S. Lat. 154° 28′ E. Long	2.077
9	27th Aug., 1923	34° 10′ S. Lat. 152° 21′ E. Long	2.094
10	28th Aug., 1923	Sydney Harbour	2.023

salinity on the Australian coast-line may be due to the vicinity of the great land mass causing greater evaporation; but this does not account for the rise to the west of New Zealand.

Further evidence of constancy in the chlorine constituent over short periods is afforded by comparison of the results from the Tasman Sea with those of New South Wales coasts. The sample taken just off Sydney Heads (No. 9) agreed exactly with other samples collected off various points of the New South Wales coast-line over a week later.

New Zealand Samples.—A study of the comparative salinities of water samples taken on our coasts appears to prove that, given equable weather conditions, there is no difference in general salinity at this season between North Auckland and Stewart Island. Save for the influence of the Taieri and Clutha Rivers we are at a loss to account for the salinity on the east coast of Otago, which at Bluff and St. Clair was found to be lower than might have been expected, while at Port Chalmers and Warrington the average rose distinctly. Though taken some distance from the river mouth, the Oamaru sample showed distinctly the influence of the Waitaki River. There is a possibility that throughout the year the Canterbury Bight and the east coast of Otago have a lower average inshore salinity than most other parts of New Zealand. The rise in salinity at Stewart Island would appear to show that no influence of large bodies of fresh water ice melting at the Antarctic affected the most southern limits of the New Zealand coast-lines at this time. In general, salinity around New Zealand is distinctly lower than found in the case of Australian samples.

Salinity in relation to Plankton.—We have found that marine diatoms cease movement in a few minutes when transferred to water of 1.5% salinity, and similarly that freshwater infusorians and diatoms cease movement in a like solution. In each case, as far as we could ascertain, the organisms ultimately died. As far as our examinations of river water in New Zealand have gone, living organic life has been small. The Clutha River in Otago is estimated to discharge into the sea 1,000,000 cubic feet of water per minute. The sea which it meets contains always quantities of diatoms which will ultimately die or are prevented from increasing by the influx of freshwater, while all organic material in the freshwater of the river is killed and finds a resting place in the bed of the ocean off the mouth of the river. Where a river discharges its contents into the sea, this process has been going on for ages. Eddies and minor currents carry the river water and its refuse along the coast in varying directions according to weather and tide conditions. Heavy rains must also be responsible for loss of considerable quantities of marine plankton. In the open seas, particularly in tropical zones where salinity and temperature are highest, denitrifying bacteria have been shown to cause enormous destruction of diatoms; but that denitrifying bacteria could increase to the same extent in areas of low salinity appears improbable.

Latitude.—Latitude is an undoubted factor in dealing with comparative salinities of ocean areas, for latitude and trade winds determine approximately the amount of heat and hence the degree of evaporation likely to occur. As a possible solution for the high degree of salinity in water from South Australia, we may mention that there is a possibility that the great land areas adjoining, with warm winds from the interior, would cause an evaporation more intense than elsewhere in Australia or New Zealand. Furthermore, there is the possibility that water in the Spencer Gulf and probably in the Australian Bight is held in a kind of pocket outside the influence of minor currents and eddies. Actually Port

Salinity Determinations of Water Samples collected around New Zealand at Full Tide on 6th September, 1923.

No.	Locality.	Collected by	Chlorine per cent.
1	Mangonui (S.S. Clansman)	S. J. Weston	1.988
2	Whananaki (North Auckland)	W. Nimmo	2.006
3	1 m. S. Tiri Tiri (S.S. Manaia) ..	W. Hizard	1.935
4	Near Sail Rock (S.S. Ronaki)	(per S. Reid)	2.041
5	Little Barrier Island	Caretaker	2.023
6	Puhoi Wharf (S.S. Omana)	F. Nichols	0.302
7	5 mls. S.E. Slipper Isl. (S.S. Ngapuhi)	R. T. Mudie	2.059
8	N.E. Kawau Isl. (S.S. Apanui)	A. W. Price	2.041
9	2 mls. Whangarei (S.S. Mahurangi)	(per S. Reid)	2.041
10	Hauraki Gulf, 27 mls. Pt. Fitzroy (S.S. Waiotaki)	W. N. Stone	2.023
11	Inner Harbour, Auckland (S.S. Claymore)	H. Lister	1.935
12	Auckland, Queen's Wharf	W. Ponsford	1.952
13	Tararu, Thames (S.S. Wakatere) ..	E. L. Baggertrom	1.899
14	Thames Wharf	J. R. Miles	1.846
15	37° 38′ S. 177° E., Bay of Plenty ..	Capt. E. W. Aspden	2.077
16	36° 43½′ S. 175° 49½′ E. Bay of Plenty	Capt. E. W. Aspden	2.059
17	Moturiki, Bay of Plenty	Dr. Bucknill	2.023
18	Te Awaroa, E. Cape	J. I. Miller	1.970
19	Gisborne Roadstead (S.S. Flora) ..	(per D. Carter) ...	1.970
20	Wairui Beach, Gisborne	F. Foote	2.006
21	New Wharf, Petone	W.J.P.	1.970
22	Old Wharf, Petone	W.J.P.	1.970
23	Off Ward Island, Port Nicholson ..	G. N. Shaw	1.952
24	Somes Island, Port Nicholson	G. N. Shaw	1.988
25	Off Point Jerningham	Capt. Inkster	1.118
26	Off Point Jerningham	Capt. Inkster	1.828
27	Off Point Halswell	Capt. Inkster	1.988
28	Ferry Wharf, Pt. Nicholson	Capt. Inkster	1.988
29	Urenui Beach	Miss Wyn. Sheard	2.006
30	Urenui Beach	J. Carr	1.544
31	Raglan Beach	W. R. Moore	1.935
32	Waikato Heads (S.S. Arapawa) ...	F. W. Pressley	1.704
33	Off Manakau Heads (S.S. Rarawa)	Alex. Brown	2.005
34	Wairopa Channel, Manakau (S.S. Rimu)	J. Blackwood	1.828
35	Pelorus Sound	F. Godsiff	1.935
36	Picton Wharf	Capt. T. Barnsdale	1.970
37	Tory Channel, Queen Charlotte Sound	M. Kenny	2.006
38	The Wharf, Westport	A. J. Tointon	0.089
39	Off Flagstaff, Westport	A. J. Tointon	2.006
40	½ ml. from Hokitika R. mouth	W. B. Braddon	1.935
41	Okarito	H. Friend	2.023
42	Half Moon Bay, Stewart Island ...	Mrs. A. Gregg	2.006
43	Bluff	(per G. C. Carnie)	1.935
44	St. Clair	Headmaster	1.935
45	Dunedin Wharf	R. F. Phillipps ...	1.917
46	Port Chalmers	Sec., Otago Har. Bd.	1.988
47	Warrington	H. McQueen	1.952
48	Oamaru	H. Hall	1.278
49	Timaru	(Rector, High School)	1.970
50	Lyttelton	T. W. Hunter	1.952
51	Akaroa	Chas. Hall	1.597

Pirie has a higher latitude than Cape Maria Van Diemen. New Zealand samples were taken between 47° and 34° South Lat., and Australian samples between 23° and 40° South Lat. Weather records showed a uniformity of good weather throughout New Zealand on 6th September, 1923.

We conclude that all fresh water from rivers or rain undoubtedly destroys or retards the growth of certain marine organisms which help to form the ultimate food of the fishes. River and stream water organisms, in however small quantities, perish on arrival in the ocean. Marine plankton and the copepods and other crustacea, as well as other minute vegetable feeders, would thus be more common at a distance from the mouths of rivers; and as if in proof of our contention, we find the largest coastal fishing grounds to be well away from the mouths of large rivers. There are, of course, many fish which enter and remain in brackish water from choice; but these do not constitute any very considerable portion of the total food fishes of Australasia, as they are less particular in choice of food and often become less desirable for human consumption after continued residence in brackish water.